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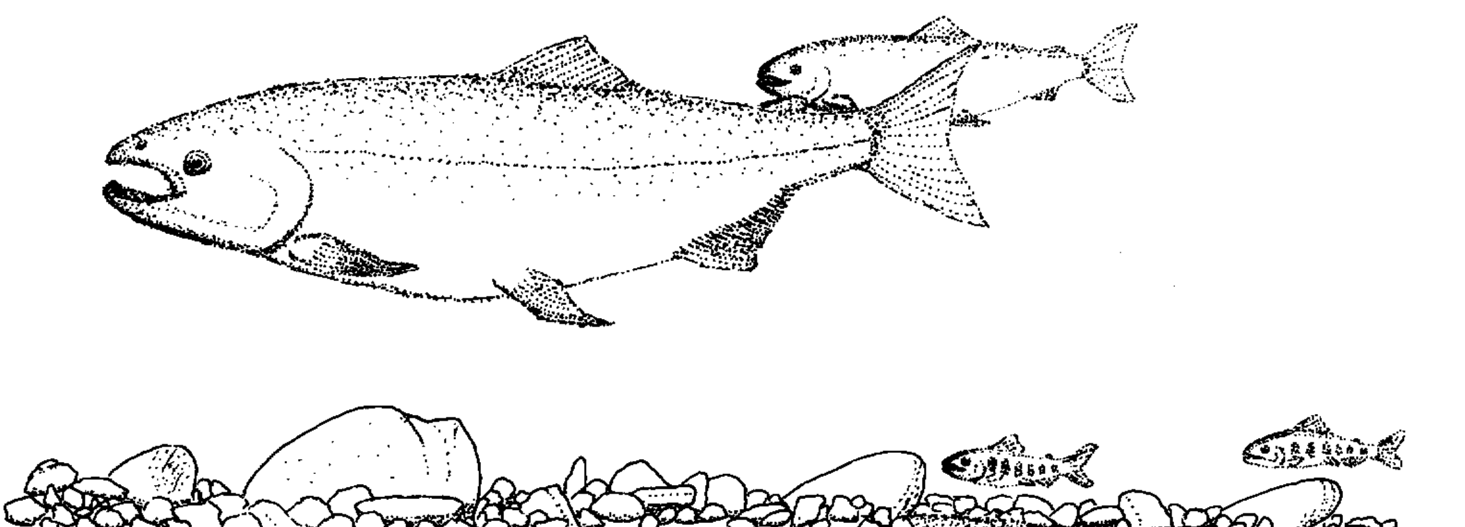
HABITAT PREFERENCE CURVES FOR HATCHERY-REARED JUVENILE FALL CHINOOK SALMON IN A SMALL WESTERN WASHINGTON STREAM



HABITAT PREFERENCE CURVES FOR HATCHERY-REARED JUVENILE FALL CHINOOK SALMON IN A SMALL WESTERN WASHINGTON STREAM

by

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ABSTRACT

Habitat preference curves, that is, habitat utilization curves adjusted to reflect true preference by fish relative to actual habitat availability, were developed for rearing fall chinook salmon. Fingerlings, originally reared at the Nooksack Salmon Hatchery, were observed in Kendall Creek adjacent to the hatchery. Depth, velocity, substrate, and protective cover were measured at 71 locations occupied by an estimated 5,055 fall chinook. A total of 63 additional locations were measured to describe the range of available habitat conditions. A relative preference function was calculated for each value or code of each habitat parameter, after which preference curves were constructed for each habitat parameter. It was determined that the water depth most preferred by rearing fall chinook ranged from 1.2 to 1.5 feet. The mean column velocity most preferred ranged from about 0.45 to about 1.35 feet per second. The substrate type most preferred was boulder. The protective cover type most preferred was object cover.

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INTRODUCTION

Recently the instream flow and Aquatic Systems Group (IFG), component of the Western Energy and Land Use Team, Ft. Collins, Colorado, acknowledged that improved habitat criteria curves were needed for use with the Instream Flow Incremental Methodology (IFIM). Specifically, habitat "preference" curves were needed that would theoretically remove any environmental bias with regard to a fish species and life stage selection of microhabitat conditions (P.C. Nelson 1983). Previously, all fish habitat criteria curves available were utilization curves, and were suspected of containing environmental bias. Baldrige and Amos (1981) described a procedure whereby fish utilization functions are adjusted or "normalized" through division by respective habitat availability functions. The resulting habitat preference curves, theoretically, may then be used in any IFIM analysis. However, the fish of the stream in question should be about the same mean physical size as the fish upon which the preference curves were developed.

Stempel (1984) presented habitat preference curves for spring chinook salmon fry that ranged in mean fork length from about 25 mm (American River) to 50 mm (Upper Yakima River). Ideally, preference curves should also be available for rearing fall chinook salmon (FC). Moreover, it is likely that a need will arise for preference curves for fingerling FC.

Data for rearing FC, 25 to 110 mm in length, were collected during 1984 in the Lewis River (R. Campbell, personal communication). However, the Pacific Power and Light Company, which contracted the research, reportedly does not intend to develop habitat preference curves from the data.

In May 1983, I collected habitat criteria data for fingerling FC in Kendall Creek, the hatchery stream for the Washington Department of Fisheries (WDF) Nooksack Salmon Hatchery (Figure 1). A large number of pond-reared FC had been released into Kendall Creek on May 24. Although these fish were free to descend the creek and leave the hatchery area, most remained, at least through early June. A one-lane vehicle bridge across the creek provided entry to the hatchery. Fish were fed in the stream reach extending from the creek pool at the bridge downstream to a hatchery weir, but were not fed in the reach upstream. The FC in the upper (unfed) reach were much less concentrated, but clearly displayed preferences for location in particular areas of the stream. It appeared that numbers of FC in specific localities in the upper reach could be estimated from a wading position, given the clarity of the creek water. Such numerical estimates could be related to measurements of the physical instream conditions at these localities. Additional measurements at a range of other localities where no fish were present could be gathered to reflect the remaining instream conditions available to the fish.

On the basis of discussions with the hatchery staff, I considered it virtually certain that less than 1% of all salmonids in the upper reach were of species other than FC. Some trout were present, particularly

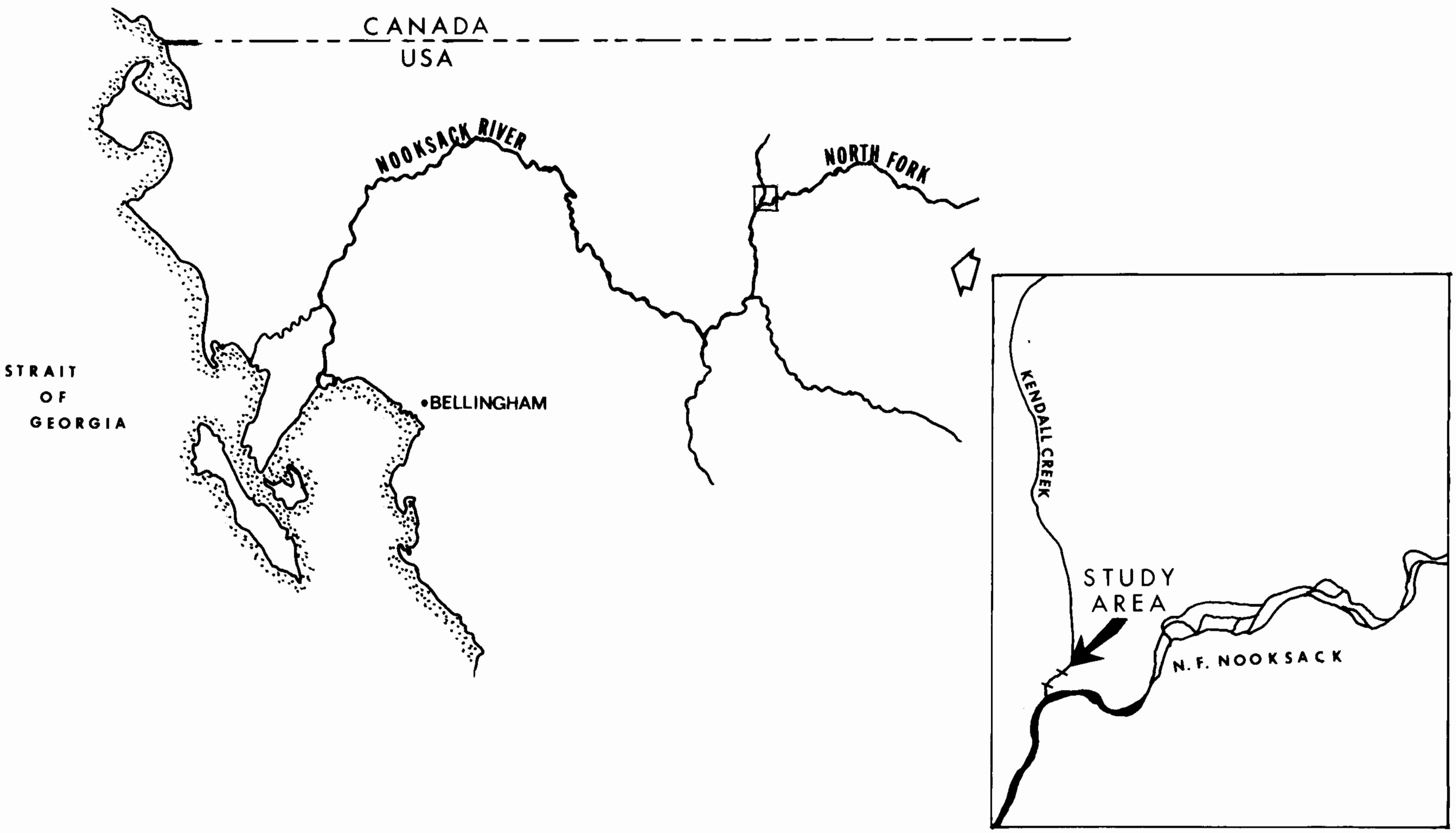

Figure 1. Location of Kendall Creek and the study area.

among the more concentrated FC in the reach below the bridge. However, they were primarily large fish.

METHODS

I collected the data discussed here during four days, May 28 - 29 and June 7 - 8, in both the morning and afternoon, within five partitioned sections of the upper creek. Stream discharge and approximate maximum water temperature were measured daily. In collecting data for fish habitat I proceeded as follows: (1) observed a creek section to be sampled for fish locations for several minutes from a downstream position; (2) made a detailed sketch of the creek section that included areas of fast or slow current, objects providing cover, bank location, and relative locations and estimated concentrations of FC (none, 20 to 50, 50 to 100, or more than 100); (3) entered the stream, taking care not to frighten fish, and made measurements of instream conditions for each fish location according to the sketch; (4) measured water depth to the nearest 0.1 foot, using a top-setting wading rod; (5) measured flow velocity at 0.6 of total depth (from the surface) using a pygmy current meter, listening headset and wristwatch, and the wading rod; (6) assessed the substrate visually for dominant and sub-dominant particle categories within a 2-foot (61-cm) radius about the fish location and recorded it by standard code (WDF 1983); and (7) assessed fish protective cover within this same radius, recording it as either no cover, object cover, overhead cover, or combined object and overhead cover.

Later calculations of fish numbers at a given location were modified by the following assigned-number estimates: N (none) = 0 fish; L (low) = 35 fish; M (medium) = 75 fish; and H (high) = 100 fish.

I collected data on available habitat and fish habitat utilization during the same general periods. The procedures used for the two data collections were identical, except that measurement of available habitat required no estimation of fish present.

Data analysis for deriving fish habitat utilization functions consisted of the following steps: (1) I transcribed all data from field notes, by stream section, and verified them for accuracy; (2) I combined the data for each variable (e.g., depth) in a single tally on which I performed frequency analysis, cluster analysis, and normalization procedures (Bovee and Cochnauer 1977); and (3) I calculated percent occurrence of total estimated number of FC within the combined locations having a specific value of a particular variable.

Data analysis for deriving available habitat functions consisted of the following: (1) a value or code of an available habitat variable was eliminated from the available habitat function development if no fish were observed using that specific value or code; (2) all measurements within a variable--both utilization and available habitat--were set equal to 12.5 square feet (the area of a circle with a radius of 2 feet (61 cm)); (3) for each variable I calculated the combined surface area at each value or code; and (4) for each value or code of a variable I calculated the percent of total (combined) surface area.

The relative preference function for each value or code of each variable was calculated by the following formula:

$$\text{relative preference function} = \frac{\text{fish habitat utilization function}}{\text{habitat availability function}} .$$

For total depth and mean column velocity, I subjected the relative preference functions of all respective values or codes to cluster analysis and normalization (Bovee and Cochnauer 1977). Substrate and protective cover preference functions were only normalized. Finally, for the continuous variables total depth and mean column velocity, curves for habitat utilization and relative preference were constructed and compared by weighting factor.

I measured fork lengths of a sample of FC taken in the pool immediately downstream of the first study section. A large dip net was used to capture FC concentrated near the pool bank. Captured fish were contained in the net, which was held in the creek, while individuals were measured and then released. Based on my observations of fish movements between the pool and the nearest study section I assumed that fish in the pool were representative of fish in the study sections. I also assumed that the sweep of the dip net in the pool captured a relatively random sample of all FC present.

RESULTS

Water temperatures measured during periods of data collection ranged between 10°C and 12.2°C. Variation in temperature was minimized by the hatchery well contribution to the flow in Kendall Creek. Creek flow at the downstream sampling section was measured on May 28 and June 7, and on both occasions the calculated discharge was 32.5 cubic feet per second. Mean stream width across the ends of the sampled stream sections was 19 feet (5.8m). Water clarity was excellent during all sampling periods.

The physical microhabitat opportunities available in the upper Kendall Creek reach appeared to be typical of those in many small streams in western Washington. Flow velocities during sampling ranged from nil to nearly 3.6 feet per second (f/s). Water depths varied considerably, but did not exceed 2.0 feet (61 cm) in the study sections. Instream substrate types present were dominated by rocks having diameters greater than 3 inches (7.6 cm); however, smaller types such as sand or small gravel were frequently observed deposited downstream of large cobbles and boulders. Large boulders were often near stream banks, and the fastest currents were generally at mid-stream. The stream banks and adjacent stream areas frequently contained overhanging riparian vegetation, particularly limbs of bushes and trees. Some parts of the study reach contained a significant amount of shading from riparian vegetation. This reach of the creek was best classified as a run; however, a number of near-bank areas could be described as small pools.

Water quality was assumed to be excellent since no indications of chemical or nutrient imbalance were seen. Both instream and terrestrial prey items (not sampled) appeared to be plentiful.

A total of 75 FC collected in the bridge pool were measured on June 7, 1984. Mean fork length was 9.0 cm (SD, 0.59 cm). Fish were not weighed, but their condition appeared to be very good. Because only a few days had passed since all fish were released from the hatchery pond, I assumed that a mean fork length of 9.0 cm was representative of FC size throughout the creek.

When data collection was begun on May 28, I observed that the FC accepted my presence more readily then might be expected of similar FC of totally wild origin. This behavior made possible the relatively accurate and consistent estimation of fish numbers.

An estimated 5,055 FC were observed at the 71 locations in the upper reach measured for fish utilization. A total of 63 additional locations were measured for available habitat conditions (Appendix, table 1).

Tables 1 and 2 present results of fish utilization analyses for value frequency, cluster selection, normalization, and percent fish occurrence at all values for total depth and mean column velocity, respectively. Cluster selection was based primarily on the least value of standard deviation calculated for differences between cluster values. Assignment of weighting factors required some subjectivity, particularly in assignments among the highest and lowest values of the variables. Percent occurrence was calculated by dividing individual frequency values by 5,055, the estimated total number of FC.

Tables 3 and 4 present results of fish utilization analyses for the variables substrate (dominant only) and protective cover, respectively. Unlike the continuous variables, depth and velocity, it was inappropriate to perform cluster analysis on these discontinuous variables. Instead normalization was performed on the unclustered frequencies. The procedure for percent fish occurrence calculations was unchanged.

Before relative preference functions can be determined, the habitat functions must be derived by calculating percent occurrence of each value or code in the combined available habitat area of a variable. Tables 5-8 present results of calculations to determine these percent occurrences.

Having determined both percent fish occurrences for fish utilization (fish habitat utilization function) and percent value or code occurrence in the combined habitat area (habitat availability function) it was then possible to calculate relative preferences. Tables 9-12 present calculated relative preference ratio values and normalized preference weighting factors for the four habitat variables.

Relative preference curves were constructed for the continuous variables, total depth and mean column velocity (Figures 2 and 3). Respective habitat utilization curves are graphed with the relative preference curves for comparison.

Table 1. Frequency analysis, cluster selection, normalization, and percent fish occurrence for fish utilization total depth measurements. Horizontal lines separate weighted intervals of depth values.

Water Depth (ft.)	Selected Cluster	Fish Frequency	Cluster	Normalization Weighting Factor	Percent Fish Occurrence
0.5	35	-- 35	70	.02	0.7
0.6	205	35			0.7
0.7		170	550	.14	3.4
0.8	515	380			7.5
0.9		135	650	.36	2.7
1.0	1240	515			10.2
1.1		725	1645		14.3
1.2	1615	920		1.00	18.2
1.3		695	1140		13.7
1.4	900	445			8.8
1.5		455	740	.63	9.0
1.6	320	285			5.6
1.7		35	110	.22	0.7
1.8	75	75			1.5
1.9		0	150		0.0
2.0	150	-- 150		.08	2.97

Table 2. Frequency analysis, cluster selection, normalization, and percent fish occurence for fish utilization mean column velocity measurements. Horizontal lines separate weighted intervals of velocity values.

Mean Column Velocity(f/s)	Selected Cluster	Fish Frequency	Clusters	Normalization Weighting Factor	Percent Fish Occurrence
0.0-0.09					
0.10-0.19	75	75	110	.11	1.50
0.20-0.29	270	35			0.69
0.30-0.39		235	435	.39	4.65
0.40-0.49	925	200			3.96
0.50-0.59		725	925		14.30
0.60-0.69	595	200			3.96
0.70-0.79		395	870		7.80
0.80-0.89	675	475		1.00	9.40
0.90-0.99		200	375		3.96
1.00-1.09	545	175			3.46
1.10-1.19		370	470		7.30
1.20-1.29	700	100			1.98
1.30-1.39		600	890		11.87
1.40-1.49	325	290			5.74
1.50-1.59		35	220		0.69
1.60-1.69	445	185		.56	3.66
1.70-1.79		260	260		5.14
1.80-1.89	70	0			0.0
1.90-1.99		70	105		1.38
2.00-2.09	185	35		.19	0.69
2.10-2.19		150	255		2.97
2.20-2.29	140	105			2.08
2.30-2.39		35	35		0.69
2.40-2.49	0	0			0.0
2.50-2.59		0	0		0.0
2.60-2.69	70	0		.05	0.0
2.70-2.79		70	105		1.38
2.80-2.89	35	35			0.69

Table 3. Frequency analysis, normalization, and percent fish occurrence for fish utilization dominant substrate observations.

Substrate Description	Code	Fish Frequency	Normalization Weighting Factor	Percent Fish Occurrence
organic detritus	0	0		0.0
silt, clay	1	0		0.0
sand	2	545	.39	10.8
small gravel	3	0		0.0
medium gravel	4	185	.13	3.7
large gravel	5	110	.08	2.2
small cobble	6	1145	.81	22.7
large cobble	7	1250	.89	24.7
boulder	8	1410	1.00	27.9
bedrock	9	410	.29	8.1

Table 4. Frequency analysis, normalization, and percent fish occurrence for fish utilization protective cover observations.

Protective cover Description	Code	Fish Frequency	Normalization Weighting Factor	Percent Fish Occurrence
no cover	1	100	.04	2.0
object	2	1080	.47	21.4
overhead	3	2320	1.00	45.9
combined object and overhead	4	1555	.67	30.8

Table 5. Percent occurrence of values for total depth among combined fish utilization and available habitat surface areas.

Water depth(ft.)	Combined Available Habitat Surface Area(sq.ft.)	Percent Occurrence In Combined Habitat Area
0.4 [a]		
0.5	100.0	6.1
0.6	37.5	2.3
0.7	112.5	6.8
0.8	175.0	10.6
0.9	62.5	3.8
1.0	200.0	12.1
1.1	187.5	11.4
1.2	187.5	11.4
1.3	225.0	13.6
1.4	100.0	6.1
1.5	150.0	9.1
1.6	50.0	3.0
1.7	25.0	1.5
1.8	12.5	0.8
1.9	0.0	0.0
2.0	25.0	1.5

(a) Value eliminated because it is classified as unuseable (Baldrige and Amos 1981).

Table 6. Percent occurrence of values for mean column velocity among combined fish utilization and available habitat surface areas.

Mean Column Velocity(f/s)	Combined Available Habitat Surface Area (sq.ft.)	Percent Occurrence In Combined Habitat Area
0.0 - .09 [(a)]		
.10 - .19	50	3.0
.20 - .29	37.5	2.3
.30 - .39	62.5	3.8
.40 - .49	50	3.0
.50 - .59	125	7.5
.60 - .69	25	1.5
.70 - .79	112.5	6.8
.80 - .89	125	7.5
.90 - .99	62.5	3.8
1.00 - 1.09	37.5	2.3
1.10 - 1.19	75	4.5
1.20 - 1.29	37.5	2.3
1.30 - 1.39	100	6.0
1.40 - 1.49	100	6.0
1.50 - 1.59	25	1.5
1.60 - 1.69	87.5	5.3
1.70 - 1.79	62.5	3.8
1.80 - 1.89	75	4.5
1.90 - 1.99	50	3.0
2.00 - 2.09	25	1.5
2.10 - 2.19	25	1.5
2.20 - 2.29	50	3.0
2.30 - 2.39	37.5	2.3
2.40 - 2.49	62.5	3.8
2.50 - 2.59	37.5	2.3
2.60 - 2.69	0	0
2.70 - 2.79	37.5	2.3
2.80 - 2.89	37.5	2.3
2.89 [(a)]		

(a): Value eliminated because it is classified as unuseable (Baldrige and Amos 1981).

Table 7. Percent occurrence of codes for dominant substrate among combined fish utilization and available habitat surface area.

Substrate Description	Code	Combined Available Habitat Surface Area(sq.ft.)	Percent Occurrence In Combined Habitat Area
organic detritus	0 [a]		
silt, clay	1 [a]		
sand	2 [b]	162.5	9.8
small gravel	3 [b]	25.0	1.5
medium gravel	4	50.0	3.0
large gravel	5	37.5	2.3
small cobble	6	475.0	32.3
large cobble	7	437.5	26.3
boulder	8	350.0	21.1
bedrock	9	125.0	7.5

[a] code eliminated because it is classified as unuseable (Baldrige and Amos 1981).

[b] code not eliminated given the assumption that increased sampling would show some fish utilization in view of observed utilization of adjacent codes.

Table 8. Percent occurrence of codes for protective cover among combined fish utilization and available habitat surface area.

Protective Cover Description	Code	Combined Available Habitat Surface Area(sq.ft.)	Percent Occurrence In Combined Habitat Area
no cover	1	12.5	0.8
object	2	275.0	16.5
overhead	3	612.5	36.8
combined object and overhead	4	762.5	45.9

Table 9. Relative preference curve development for total water depths. Horizontal lines separate weighted intervals of depth values.

Water Depth(ft.)	Utilization, Percent Fish Occurrence	Habitat Availability Percent Occurrence In Combined Area	Relative Preference Ratio	Weighting Factor
0.5	0.7	6.1	0.115	.05
0.6	0.7	2.3	0.304	.32
0.7	3.4	6.8	0.500	
0.8	7.5	10.6	0.708	.56
0.9	2.7	3.8	0.711	
1.0	10.2	12.1	0.843	.83
1.1	14.3	11.4	1.254	
1.2	18.2	11.4	1.596	
1.3	13.7	13.6	1.007	1.00
1.4	8.8	6.1	1.443	
1.5	9.0	9.1	0.989	
1.6	5.6	3.0	1.867	
1.7	0.7	1.5	0.467	
1.8	1.5	0.8	1.875	.82
1.9	0.0	0.0	0.000	
2.0	2.97	1.5	1.980	

Table 10. Relative preference curve development for mean column velocities. Horizontal lines separate weighted intervals of velocity values.

Mean Columan Velocity (f/s)	Utilization, Percent Fish Occurrence	Habitat Availability, Percent Occurrence In Combined Area	Relative Preference Ratio	Preference Weighting Factor
.10 - .19	1.50	3.0	0.500	.16
.20 - .29	0.69	2.3	0.300	
.30 - .39	4.65	3.8	1.224	.50
.40 - .49	3.96	3.0	1.320	
.50 - .59	14.30	7.5	1.907	
.60 - .69	3.96	1.5	2.640	
.70 - .79	7.80	6.8	1.147	
.80 - .89	9.40	7.5	1.253	1.00
.90 - .99	3.96	3.8	1.042	
1.00 - 1.09	3.46	2.3	1.504	
1.10 - 1.19	7.30	4.5	1.622	
1.20 - 1.29	1.98	2.3	0.861	
1.30 - 1.39	11.87	6.0	1.978	
1.40 - 1.49	5.74	6.0	0.957	
1.50 - 1.59	0.69	1.5	0.460	
1.60 - 1.69	3.66	5.3	0.691	
1.70 - 1.79	5.14	3.8	1.353	.84
1.80 - 1.89	0.0	4.5	0.0	
1.90 - 1.99	1.38	3.0	0.460	
2.00 - 2.09	0.69	1.5	0.460	
2.10 - 2.19	2.97	1.5	1.980	
2.20 - 2.29	2.08	3.0	0.693	
2.30 - 2.39	0.69	2.3	0.300	
2.40 - 2.49	0.0	3.8	0.0	
2.50 - 2.59	0.0	2.3	0.0	.15
2.60 - 2.69	0.0	0.0	0.0	
2.70 - 2.79	1.38	2.3	0.600	
2.80 - 2.89	0.69	2.3	0.300	

Table 11. Relative preference curve development for substrate.

Substrate Description	Code	Utilization Percent Fish Occurrence	Habitat Availability, Percent Occurrence In Combined Area	Relative Preference Ratio	Preference Weighting Factor
organic detritus	0	0.0			
silt, clay	1	0.0			
sand	2	10.8	9.8	1.102	.83
small gravel	3	0.0	1.5	0.0	
medium gravel	4	3.7	3.0	1.233	.93
large gravel	5	2.2	2.3	.957	.72
small cobble	6	22.7	32.3	.703	.53
large cobble	7	24.7	26.3	.939	.71
boulder	8	27.9	21.1	1.322	1.00
bedrock	9	8.1	7.5	1.080	.82

Table 12. Relative preference curve development for protective cover.

Substrate Description	Code	Utilization Percent Fish Occurrence	Habitat Availability, Percent Occurrence In Combined Area	Relative Preference Ratio	Preference Weighting Factor
No cover	1	2.0	0.8	2.500	0.10
object	2	21.4	16.5	1.297	1.00
overhead	3	45.9	36.8	1.247	.96
combined object and overhead	4	30.8	45.9	0.671	.52

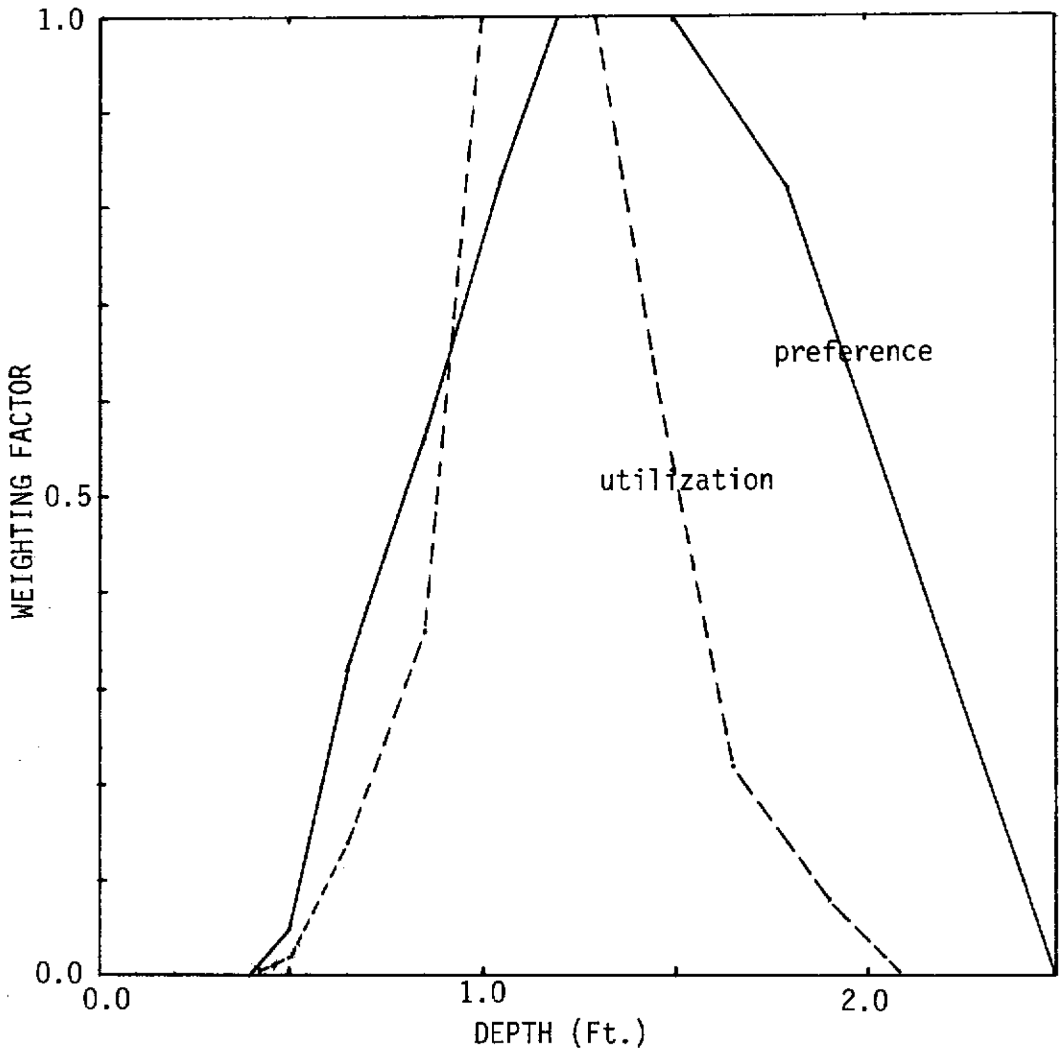

Figure 2. The curve for relative preference of total depth compared to the utilization curve.

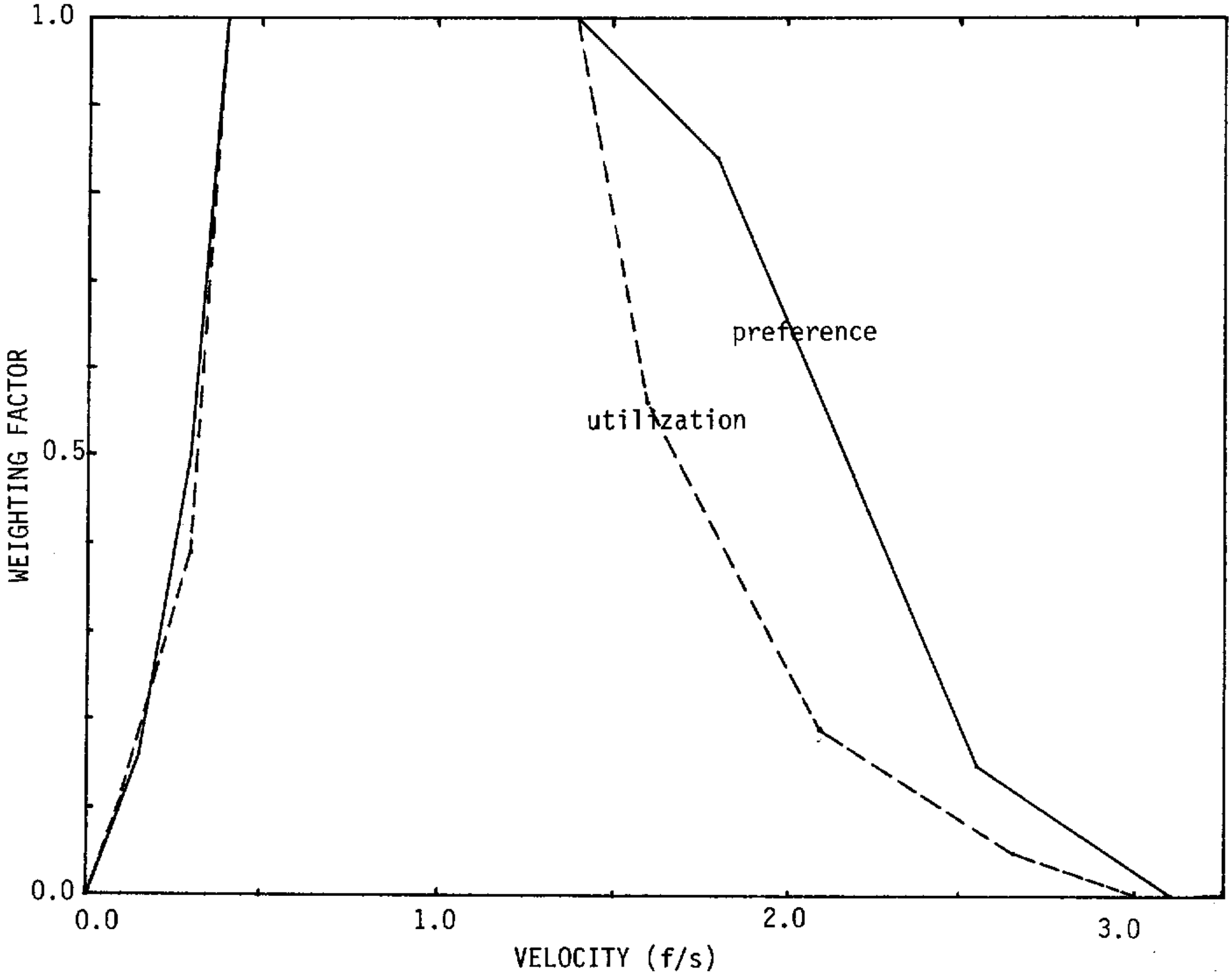

Figure 3. the curve for relative preference of mean column velocity compared to the utilization curve.

DISCUSSION

The circumstances that existed during this study require that users of the resulting relative preference curves be aware of the following assumptions: (1) given the presence of so many FC in the study reach it is assumed that most, if not all, preferred microhabitat was occupied by FC; (2) the relative absence of FC in microhabitat locations containing conditions not preferred, particularly the fastest flow velocities, indicated that the number of FC present was not excessive, and that fish were not forced into conditions not preferred; (3) microhabitats occupied by fish at the time of sampling, plus additional available microhabitats sampled, included the full range of, and correct proportions of, conditions available to FC; (4) FC were not driven by human presence into microhabitat locations not preferred; (5) availability of hatchery food downstream of the study reach did not influence FC behavior in the study reach; (6) absence within the study reach of water depths exceeding 2.0 feet did not influence FC distribution among lesser depths; and (7) visual estimates made of number of FC at a stream location were reasonably accurate and consistent over all estimates.

An important question regarding the use of these relative preference curves is whether they can appropriately be used to represent any fingerling FC in any small stream. It is true that the behavior of these FC, particularly their general lack of fear of a human, was atypical of totally wild FC behavior. However, these FC appeared to have adjusted to the physical demands of their new environment. As with any wild stock rearing FC, they instinctively responded to the forces of varied flow velocities, avoiding the faster currents and using object cover to reduce their energy loss while maintaining constant stream position. The fact that these FC did not take flight and hide in response to human presence seems to have eliminated one of the more important obstacles faced in collecting habitat preference data, namely, frightening fish from the microhabitat conditions that they actually prefer. Such observations support the view that these preference curves should be applicable to general use for similar-sized FC in small streams.

Recent habitat criteria work performed in the Lewis River (R. Campbell, personal communication), a large stream, lends support to the view that the FC in Kendall Creek displayed typical behavior. The FC observed by snorkeling in the Lewis River ranged in fork length from about 2.5 to 11 cm. Although individuals were occasionally observed in the faster currents present, they remained there for only a brief period. Most FC schooled in areas of reduced velocity, as was generally the case in Kendall Creek.

The importance of deriving preference curves based upon the relationship between utilized microhabitat and total available microhabitat became apparent from data analysis. When ranges of weighting factors for fish utilization variables (Tables 1 to 4) were compared to those for respective relative preference variables (Tables 9 to 12) some significant adjustments were evident. Of the continuous variables, total depth and mean column velocity, the greatest adjustment occurred in total depth, depicted graphically in figure 2. The shift of the total depth preference curve toward greater depth demonstrates that a disproportionately large number of FC were observed in deeper water relative to the availability of deeper water. No change occurred for mean column velocity maximum weighting range, but some shifting to greater preferred velocities was found above the maximally weighted range.

Comparison of weighting factors for respective dominant substrate classes in the fish utilization analysis (Table 3) and in the preference curve (Table 11) shows that major adjustment resulted. While normalization was based on the boulder class for both utilization and preference analyses, all other weighted classes changed, some quite significantly.

Calculation of preferred protective cover weighting also resulted in significant adjustments from respective fish utilization weightings (Tables 4 and 12). While cover for utilization was normalized on overhead cover, it was normalized on object cover for the preference curve. Other shifts were relatively small. However, if not for my decision to override the recommended normalization calculation procedure, this preference curve would be quite different. A single measurement of fish at a location containing no cover would have resulted in assigning no cover the maximum preference weighting. But, because only 2 percent of all fish were observed at that location, it was assumed to be an anomaly. Therefore, the category "no cover" was not used to normalize the others. Instead it was subjectively assigned a weighting of 0.10.

The adjustments seen in weighting these preference curves appear to confirm the need to develop habitat suitability curves that reflect actual preference relative to total microhabitat availability.

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APPENDIX

Table 1. Combined fish utilization and available habitat variable data. Available habitat data is distinguished by assignment of the letter code "N" for fish concentration.

Creek Section	Measurement Location	Fish (a) Concentration	Water Depth(ft.)	Water Velocity(f/s)	Substrate Code (b) Dominant	Subdominant	Protective Cover (c)
1	1	M	1.6	0.52	8	9	4
	2	H	1.5	0.62	8	9	4
	3	H	1.6	0.92	8	2	3
	4	H	1.1	0.48	8	2	2
	5	H	1.2	1.12	8	7	4
	6	H	1.1	0.92	9	7	4
	7	N	1.3	0.17	7	2	3
	8	M	1.3	0.12	7	2	3
	9	N	1.0	0.17	9	7	4
	10	N	1.1	1.60	9	8	4
	11	N	0.9	2.06	8	7	3
	12	N	1.0	1.97	8	7	3
	13	H	1.3	1.32	2	7	1
	14	H	0.8	0.47	2	7	4
	15	H	0.9	0.34	9	8	4
	16	H	0.8	1.10	7	2	2
	17	M	1.6	2.17	9	3	4
	18	M	1.2	2.10	8	7	3
	19	L	1.0	2.71	7	2	3
	20	L	0.7	0.23	2	3	2
	21	L	1.6	2.30	9	3	4
	22	L	1.3	1.47	8	7	3
	23	N	1.7	2.47	9	8	4
	24	N	1.2	2.59	9	2	4
	25	H	0.7	0.34	2	8	3
	26	L	0.8	1.42	7	4	3
	27	H	1.0	0.55	7	4	3
	28	M	1.2	1.77	8	7	3
	29	H	1.2	0.64	8	2	3
	30	N	0.8	2.83	9	8	4
	31	N	0.5	1.55	8	7	4
	32	N	0.6	2.45	7	8	2
	33	L	0.5	1.12	2	4	4
	34	L	1.2	2.76	8	7	4
	35	L	0.6	1.92	8	2	2
2	36	H	1.3	0.82	9	2	2
	37	M	1.2	1.62	2	7	4
	38	M	1.2	0.77	8	7	3
	39	N	1.0	2.76	8	2	3
	40	H	1.1	0.77	2	8	2
	41	H	1.0	0.87	8	2	2
	42	H	1.1	0.52	8	7	2
	43	L	1.0	1.62	8	7	4
	44	L	1.5	2.20	8	2	4
	45	H	1.0	0.82	8	2	2

Table 1 (continued)

Creek Section	Measurement Location	Fish (a) Concentration	Water Depth(ft.)	Water Velocity(f/s)	Substrate Code (b) Dominant	Subdominant	Protective Cover (c)
3	46	N	0.8	1.20	6	9	2
	47	N	1.3	1.47	7	3	2
	48	N	1.3	1.72	7	8	4
	49	N	0.8	0.82	7	8	4
	50	N	0.5	1.85	4	6	4
	51	N	0.7	1.17	6	8	2
	52	N	0.6	0.23	6	2	4
	53	N	0.5	0.06	6	2	3
	54	N	0.7	0.10	6	7	4
	55	H	1.4	1.26	7	6	3
	56	N	0.7	0.23	6	7	4
	57	L	1.0	1.70	7	6	3
	58	N	1.5	2.38	7	2	3
	59	L	1.4	1.51	7	6	3
	60	N	1.3	2.47	7	6	3
	61	L	1.7	1.90	6	5	3
	62	L	1.3	2.20	6	7	3
	63	L	1.5	1.45	7	6	3
	64	M	2.0	1.65	6	7	4
	65	M	2.0	1.40	7	6	4
	66	H	1.5	1.07	7	2	2
	67	H	1.3	0.57	8	7	4
	68	L	1.0	0.31	6	2	4
	69	N	0.5	0.57	7	8	4
	70	H	1.4	0.52	7	2	3
	71	H	1.4	1.35	7	6	3
	72	M	1.8	0.57	7	2	3
	73	M	1.3	0.57	7	2	4
	74	N	1.0	1.87	7	8	4
	75	N	0.9	0.90	2	3	2
4	76	N	1.0	1.85	8	7	4
	77	N	1.2	3.31	7	8	3
	78	L	0.8	0.77	5	2	2
	79	N	0.5	1.82	8	7	4
	80	N	0.4	0.57	7	8	2
	81	N	1.0	2.98	6	7	3
	82	N	1.5	1.82	8	7	3
	83	N	1.3	1.02	6	2	4
	84	N	1.4	0.87	2	8	4
	85	N	1.5	0.80	6	7	4
	86	L	0.9	2.81	6	8	4
	87	M	1.4	1.40	7	2	3
	88	N	0.5	0.77	6	7	2
	89	M	1.1	1.72	6	5	3
	90	L	1.5	2.07	6	7	3
	91	N	1.1	1.65	6	7	3

Table 1 (continued)

Creek Section	Measurement Location	Fish Concentration (a)	Water Depth(ft.)	Water Velocity(f/s)	Substrate Code (b) Dominant	Subdominant	Protective Cover (c)
4	92	N	1.5	2.05	6	2	4
	93	N	1.3	0.87	7	5	4
	94	N	1.1	1.90	8	4	4
	95	N	1.3	1.62	7	3	4
	96	N	0.7	0.44	6	7	4
	97	N	1.4	3.55	6	5	4
	98	N	0.5	0.31	2	6	4
5	99	N	0.8	2.42	7	3	4
	100	N	0.8	2.83	7	6	4
	101	N	0.8	2.38	6	7	4
	102	M	0.8	1.05	4	2	4
	103	L	0.7	0.77	4	2	3
	104	M	1.0	0.82	4	2	2
	105	H	1.1	1.15	6	3	2
	106	N	0.7	0.39	2	6	3
	107	N	1.0	2.20	6	8	4
	108	H	1.3	0.57	7	3	3
	109	N	1.3	1.62	7	3	3
	110	N	1.0	0.97	3	8	4
	111	N	1.2	1.32	6	3	4
	112	N	1.1	0.90	2	7	2
	113	N	1.1	2.54	6	4	2
	114	N	0.8	0.77	2	6	4
	115	M	1.5	1.32	5	2	4
	116	H	1.2	0.87	6	2	3
	117	N	0.8	1.42	5	2	4
	118	M	1.3	1.32	6	5	3
	119	N	1.5	1.82	7	6	3
	120	M	1.5	1.35	6	7	4
	121	N	1.1	1.27	6	7	4
	122	N	1.1	0.44	7	6	4
	123	M	1.1	0.72	6	3	3
	124	M	1.2	1.35	6	3	3
	125	N	0.7	0.77	6	3	3
	126	M	1.1	0.70	6	3	3
	127	M	1.2	1.72	6	7	3
	128	L	1.4	2.28	6	2	4
	129	N	0.9	0.80	8	7	4
	130	N	1.3	2.45	3	7	4
	131	L	1.2	1.47	6	3	3
	132	H	1.2	1.30	6	3	3
	133	L	0.8	1.17	8	3	3

Table 1 (continued)

(a) Fish concentration code, as used during data collection:

N = no FC observed at the sampled location
L = from 20 to 50 FC observed
M = from 50 to 100 FC observed
H = more than 100 FC observed

(b) Substrate code (WDF 1983):

Description and Particle Size Diameter	Code
organic detritus	0
silt, clay 2.0 mm	1
sand, 2.0 mm	2
small gravel, 2.0 mm - 0.5 inches	3
medium gravel, 0.5 - 1.5 inches	4
large gravel, 1.5 - 3.0 inches	5
small cobble, 3.0 - 6.0 inches	6
large cobble, 6.0 - 12.0 inches	7
boulder, 12.0 inches	8
bedrock	9

(c). Protective Cover:

Description	Code
no cover	1
object cover	2
overhead cover	3
combined object and overhead cover	4